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Endoscopic Radial Artery Harvest for Coronary Artery Bypass Grafting: Initial Clinical Experience

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ABSTRACT

Background: Recently, an endoscopic technique was developed to harvest the radial artery (RA) via a 3-cm wrist incision in patients undergoing coronary artery bypass graft (CABG). The aim of this study was to evaluate our initial clinical experience with this technology.

Methods: Data were prospectively collected on 75 consecutive patients undergoing CABG with endoscopic RA harvest using the Ultra-Retractor (CardioVations, Somerville, NJ, USA) and the harmonic scalpel (Ethicon Endo-Surgery, Cincinnati, OH, USA).

Results: There were 66 men (88%) and 9 women (12%) with a mean age of 60 years (range, 31-77 years). Forty-eight (64%) of cases had non-elective surgery. Thirty-one (41%) of patients had diabetes. Sixty seven percent of the operations were performed on pump and 33% off pump. Average RA harvest time was 66 minutes (range, 25-120 minutes) with a significant learning curve (75 minutes for the first 20 cases and 63 minutes for the last 50 cases). Two (2.6 %) radial arteries were discarded, one because of extensive calcifications and the other because of damage to the conduit. No patients suffered death, perioperative myocardial infarction, or stroke. There was one reexploration of the forearm for a tunnel hematoma. Follow-up was achieved in 100% of patients and averaged 3.6 months (range, 0.5-13 months). Two patients died during the follow-up. There were no myocardial infarctions or reinterventions, with 96% of patients in functional class I /II. There were no motor deficits. There were no sensory deficits in the distribution of the lateral antebrachial cutaneous nerve, but transient mild dorsal thenar numbness or paresthesias were observed in 86% of patients. Cosmetic results were defined as good to excellent in 82% of patients.

Conclusions: Short-term results of endoscopic RA harvest are excellent. There is a significant learning curve. Long-term follow-up as well as structural and functional assessments of the conduit are indicated.

BACKGROUND

The use of the radial artery for coronary artery bypass grafting (CABG) was first introduced by Carpentier and colleagues in the early 1970s [Carpentier 1973]. Radial artery use was abandoned shortly thereafter because of early graft occlusion attributed to vasospasm and accelerated intimal hyperplasia [Curtis 1975, Fisk 1976] but was rejuvenated by Acar and colleagues following anecdotal observations that some radial artery grafts remained patent more than 20 years after surgery [Acar 1998]. Subsequently, Acar and many other groups reported markedly improved early and midterm patency rates and excellent clinical results with the radial artery graft [Acar 1998, Shapira 1997, Tatoulis 2002, Caputo 2003]. Improved results were attributed, at least in part, to improved harvesting technique and the routine use of antispasmodic agents such as calcium channel blockers or nitrates [Acar 1998, Shapira 1999].

The key points in open harvest technique as described by Reyes and colleagues [1995] include harvesting the radial artery as a pedicle with the accompanying veins and fat, minimal manipulation of the graft (no-touch technique), minimal use of electrocautery, and avoidance of probing or hydrostatic dilation of the conduit [Reyes 1995]. Recently, many surgeons have replaced electrocautery with the harmonic scalpel for open harvest of the radial artery in an effort to further reduce the risk of thermal damage to the conduit [Posacioglu 1998, Ronan 2000, Cikirkioglu 2001, Wright 2001].

Although the overall morbidity associated with open radial harvest is low, it is still associated with complications such as bleeding and hematomas, wound infection, and sensory nerve deficits [Shapira 1997, Acar 1998, Tatoulis 1998, Royse 1999, Shapira 1999, Denton 2001, Meharwal 2001, Saeed 2001, Tatoulis 1998, Caputo 2003]. Moreover, cosmetic results were a major concern for many patients because this part of the body is so visible. In an effort to reduce the incidence of these problems, Connolly and colleagues [2002] recently described a new endoscopic technique to harvest the radial artery via a 3-cm wrist incision made using the harmonic

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scalpel. They reported excellent results in 300 patients [Connolly 2002]. We recently adopted the endoscopic radial artery technique, and in this study we sought to evaluate the short-term clinical outcomes of performance of this technique in our institution.

PATIENTS AND METHODS

Patients

Data were prospectively collected on 75 consecutive patients undergoing CABG with endoscopic radial harvest at Boston Medical Center between December 2002 and January 2004.

Operative Technique

CABG Procedure. Fifty patients (67%) underwent CABG using cardiopulmonary bypass (on pump) and 25 (33%) underwent off-pump CABG. CABG with cardiopulmonary bypass was performed with patient body temperature at near-normothermia (34°C) using heparin-bonded cardiopulmonary bypass circuits and low systemic anticoagulation (target activated clotted time, 280 seconds). Distal anastomoses were performed during single aortic cross-clamping using antegrade only or antegrade and retrograde cold blood cardioplegia. Off-pump CABG was performed using the Guidant Acrobat system (Guidant Corporation, Santa Clara, CA, USA) including a sternal retractor, a stabilizer, and an apical suction device.

Radial Artery Harvest. The radial artery was usually harvested from the nondominant hand. An Allen test was performed preoperatively to screen patients for radial artery harvest. It was repeated intraoperatively with the use of a pulse oximeter placed on the thumb to ascertain an intact palmar arch and adequate perfusion of the palm.

Endoscopic radial artery technique was performed as described by Connolly and colleagues [2002]. Briefly, the patient was placed in a supine position with the arm abducted and fixed on a board with the wrist in hyperextension. A 3-cm longitudinal skin incision starting 1 cm proximal to the radial styloid was performed. The radial artery was dissected as a pedicle with its accompanying veins and fat. The Ultra-Retractor (CardioVations, Somerville, NJ, USA) was then introduced and video-assisted dissection of the radial artery pedicle was performed with a 30° scope using the harmonic scalpel (UltraCision harmonic scalpel; Ethicon Endo-surgery, Cincinnati, OH, USA). By advancing the Ultra-Retractor 1 cm at a time and controlling the branches with the harmonic scalpel, care was taken to avoid avulsion of branches. Thermal damage to the radial artery was avoided by keeping the active blade of the harmonic scalpel away from the radial artery during coagulation of branches or tissue dissection. The dissection extended proximally to just distally to the brachial artery bifurcation. Proximal control of the radial artery was achieved with an Endo-loop ligature (Ethicon, Somerville, NJ, USA). The artery was divided with an Endo-scissors (Ethicon), gently flushed with heparinized Plasma-Lyte (Baxter Healthcare, Deerfield, IL, USA) solution and stored in a Papeverine (King Pharmaceuticals, Bristol, TN, USA) basin.

Patients were treated with intravenous nitroglycerin during the first 24 hours after the operation and then with oral nitrates for 6 to 12 months postoperatively as previously described [Shapira 1999].

Data Collection

Hospital and follow-up data were entered into the departmental database, which is part of the Society of Thoracic Surgeons (STS) database, using STS definitions for the different variables [STS 2003]. Long-term follow-up was achieved by direct contact with the patient and/or family. Sensory symptoms (paresthesias) and cosmetic results were subjectively assessed using a numerical scale of 1 to 5. A score of 1 reflected a poor result and a score of 5 reflected an excellent result. Data were expressed as mean ± SD or as absolute numbers with percentages. The Student *t* test was used to analyze continuous variables. Categorical data were analyzed using the χ^2 test with Yate`s correction for small samples. A *P* value of .05 was considered significant.

RESULTS

Patients

There were 66 (88%) males and 9 (12%) females with an average age of 60 ± 9 years (range, 31-77 years). The baseline patient profile is depicted in Table 1. Eighty percent of the patients were in angina class III or IV preoperatively.

Operative Data

Operative data are summarized in Table 2. The average number of grafts performed per patient was 3.2 ± 0.7, of which 2.2 ± 0.6 were arterial. The number of grafts performed in patients undergoing off-pump CABG (2.9 ± 0.6) was lower than in patients undergoing on-pump CABG (3.3 ± 0.7), $P < .01$.

Table 1. Baseline Patient Profile*

Age, y	60 ± 9 (median 61, range 21-77)
Sex, M/F, n	66/9
Nonelective surgery	48 (64%)
CCS angina class	
I	6 (8%)
II	9 (12%)
III	29 (39%)
IV	31 (41%)
Left ventricular ejection fraction	51% ± 15%
Hypertension	63 (84%)
Diabetes mellitus	31 (41%)
Peripheral vascular disease	7 (9%)
Smoking	50 (67%)
Predicted STS mortality	1.9%

*CCS indicates Canadian Cardiovascular Society angina class; STS mortality, predicted mortality based on the Society of Thoracic Surgeons National Database for cardiac surgery.

Table 2. Operative Data*

Grafts/patient	3.2 ± 0.7
Arterial grafts/patient	2.2 ± 0.6
Use of left internal mammary artery	72 (96%)
Use of right internal mammary artery	6 (8%)
Total no. of radial artery distal targets	85†

*Data are expressed as mean ± SD, n (%), or n.

†Two radial arteries were discarded. In 11 patients the radial artery was used a sequential graft to more than 1 distal target.

Radial Artery Harvest

Average radial artery harvest time was 66 ± 24 minutes (range, 25-120 minutes). A significant learning curve was observed. The average harvest time for the first 25 cases was 75 ± 30 minutes, dropping to 63 ±10 minutes for the last 51 cases (P = .09). These harvest times reflect the learning experience of 4 people trained during the year, 2 attending surgeons, 1 resident, and 1 physician assistant. A more representative learning curve is that of 1 surgeon with the largest experience, as depicted in Figure 1. Two radial arteries (2.6%) were discarded after the harvest, one because of extensive calcifications and the other because of damage to the conduit by the harmonic scalpel during harvesting.

Hospital Outcomes

Overall hospital outcomes are summarized in Table 3. Complications related to radial artery harvest were observed in 3 patients (4.0%). One patient (1.3%) required reexploration of the arm to evacuate a tunnel hematoma. Two patients (2.6%) developed mild superficial infection that resolved with antibiotics.

Midterm Outcomes

Follow-up was achieved in 100% of patients. Average follow-up was 3.6 months (range, 0.5-13 months). Two patients (2.6%) died during the follow-up. One patient suffered a sudden death at home 1 month after the operation. A postmortem examination was not performed. The second patient committed suicide 3 months postoperatively. At the time of follow-up 72 patients (96%) were in Canadian Cardiovascular Society class I/II, compared to 15 patients (20%) preoperatively (P < .001). There was no incidence of hand ischemia and no reported motor deficits. There were no sensory deficits in the distribution of the lateral antebrachial cutaneous nerve. However, 63 patients (86%) reported mild dorsal thenar paresthesias (grade 3-5). In most cases it subsided within 2 to 4 weeks postoperatively. Only 1 patient (1.6%) developed severe sensory symptoms in the superficial radial nerve territory. Cosmetic results were scored as good to excellent (grade 4/5) in 60 patients (82%). Comparison of a conventional harvesting incision and the endoscopic incision is depicted in Figure 2.

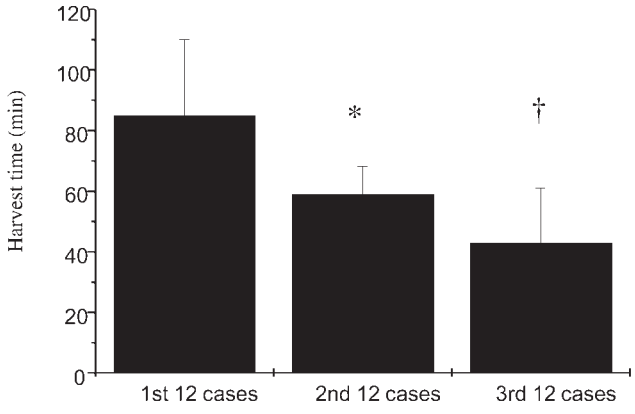

Figure 1. Endoscopic radial artery harvest: experience of a single surgeon. *P = .001 versus 1st 12 cases; †P = .016 versus 2nd 12 cases.

DISCUSSION

The radial artery is increasingly used as an alternative arterial conduit with encouraging midterm results [Shapira 1997, Acar 1998, Tatoulis 2002, Caputo 2003]. Improved results in recent years have been attributed at least in part to improved gentle no-touch harvesting technique. The radial artery is conventionally harvested via a full-length forearm incision using electrocautery as described by Reyes and colleagues [1995].

The incidence of major complications such as hand ischemia, wound infection, and hematomas with the conventional harvest approach is quite low and ranges between 0.2% and 1.5% [Shapira 1997, Acar 1998, Tatoulis 2002, Caputo 2003]. However, the incidence of sensory nerve injuries and scar-related complaints are significant. The cosmetic result in this widely exposed part of the body is a frequent cause of concern, particularly for female patients. Royse and colleagues, in a study of 2167 harvested radial arteries, found that 15.5% of patients reported sensory symptoms (sensation loss or paresthesias) in the territory of the lateral cutaneous nerve of the forearm and 11.3% in the territory of the superficial radial nerve. Moreover, 20% of patients reported scar tightness and hypersensitivity, and 5% complained of some difficulty with normal daily activity [Royse 1999]. In a study of 3977 patients Meharwal and colleagues reported a 28%

Table 3. Hospital Outcomes

Mortality, n	0 (0%)
Postoperative myocardial infarction, n	0 (0%)
Postoperative cerebrovascular accident, n	0 (0%)
Reexploration for bleeding, n	1 (1.3%)
Sternal infection, n	1 (1.3%)
Radial artery harvest–related complications, n	3 (4.0%)
Tunnel hematoma, n	1 (1.3%)
Wound infection, n	2 (2.6%)
Intensive care length of stay, h	38 ± 26
Postoperative length of stay, d	7.7 ± 3.1

Figure 2. Comparison of a conventional (above left) and 2 endoscopic (above right and below) radial artery harvest incisions.

incidence of numbness and paresthesia and 12% incidence of limitation of hand activity. Four weeks after surgery 16% of patients had sensory symptoms; 3 months postoperatively the rate dropped to 3%. Hypertrophied scarring developed during long-term follow-up in 3.6% of patients [Meharwal 2001]. In another study, Tatoulis and colleagues reported sensory loss in 10% and scar discomfort in 33% of patients. Eight percent of patients complained that the forearm incision adversely affected their work performance and 6.5% reported that they required forearm rehabilitation therapy [Tatoulis 1998]. Saeed and colleagues [2001] and Denton and colleagues [2001] reported a 67.7% and 30.1% incidence of sensory symptoms, respectively.

In an effort to reduce these complications related to full-length incisions, a technique for endoscopic harvesting of the radial artery has been developed by the group at Lenox Hill in New York. They reported excellent results in an initial series of 300 patients [Connolly 2002].

Our experience with endoscopic radial artery harvest supports the reports of Connolly and colleagues [2002] and Genovesi and colleagues [2001] and confirms that the technique is safe and effective. Only one incident of damage to the conduit during harvesting that prevented its use occurred, and this was early in our series. However, there was a significant learning curve as reflected in harvest times. We estimate that it takes approximately 20 cases for an individual operator to become comfortable with the technique. Previous surgical experience with both open radial artery harvest and endoscopic saphenous vein harvest is a major advantage that may reduce the learning curve significantly. Our experience was similar to that of the Lenox Hill group in that we were able to train physician assistants to perform this procedure, allowing for simultaneous harvest of the internal mammary artery, radial artery, and saphenous vein [Genovesi 2001, Connolly 2002].

Overall hospital and follow-up mortality and the incidence of major complications were low in this unselected group of patients. Radial artery–related complications were also very low. There was no incidence of hand ischemia or motor deficits. The endoscopic approached virtually eliminated injury to the lateral antebrachial cutaneous nerve, which is frequently injured during conventional harvest. However, injury to the superficial radial nerve was still common. We did notice a decrease in the incidence and severity of this complication recently, most likely because we gained more experience with the technique and therefore the amount of manipulation of the retractor and instruments decreased significantly, reducing trauma to the tissues in general and to the nerve specifically. Further refinements of the instruments such as using a lower-profile retractor may further reduce superficial radial nerve injury. Cosmesis associated with 3-cm wrist incision was clearly superior to the full-length conventional approach. Most patients graded the cosmetic result as good to excellent. Scar-associated problems, which were frequently reported during follow-up after the conventional approach, were virtually eliminated by the endoscopic approach.

The harmonic scalpel is an essential component of the endoscopic radial artery technique. The harmonic scalpel is used to dissect the pedicle and divide the branches in a very limited space, working in close proximity to the radial artery. The harmonic scalpel was introduced for radial artery harvest in the late 1990s [Posacioglu 1998, Ronan 2000, Cikirkcioglu 2001, Wright 2001]. The principal of harmonic scalpel technology is conversion of electrical energy to ultrasonic energy within the blade of the instrument. The harmonic scalpel blade vibrates at a frequency of 55.5 kHz, resulting in mechanical breaking of tertiary hydrogen bonds and protein denaturation [Hambley 1988, Amaral 1994]. Although there is heat generation, the harmonic scalpel works at a temperature range of 50°C to 100°C, which is substantially lower than conventional electrocautery (operating temperature range, 150°C-450°C) [Hambley 1988, Amaral 1994]. Moreover, heat transmission through the tissue is significantly greater with electrocautery compared with the harmonic scalpel [Hambley 1988, Amaral 1994]. Thus, the harmonic scalpel is much safer to use at close proximity to the vessel. Studies assessing the use of the harmonic scalpel for radial artery harvest via a conventional full-length incision showed that this technology is safe and fast and minimizes the use of metal clips [Posacioglu 1998, Ronan 2000, Cikirkcioglu 2001, Wright 2001]. Although one study documented reduced radial artery vasospasm with the harmonic scalpel [Ronan 2000], another study did not show any difference in vasoreactivity of the radial artery when tested in organ chambers [Cikirkcioglu 2001]. At present, there are no data with respect to the morphology and vasoreactivity of radial arteries harvested endoscopically.

In summary, endoscopic radial artery harvest with the harmonic scalpel can be performed safely. There is a significant learning curve. Early clinical outcomes are excellent. Injury to the lateral antebrachial cutaneous nerve was eliminated, but symptoms related to the superficial radial nerve remain a problem. Cosmetic results are superb. Further studies are indicated to evaluate the morphology and physiology of the conduit as well as long-term clinical outcomes.

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